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Berkeley, California

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J. Blok and D. A. Shirley

October 1964

# GAMMA RAY SPECTROSCOPY ON 155-DAY $Lu^{177}$ USING LITHIUM-DRIFTED GERMANIUM COUNTERS

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Berkeley, California

October 1964

We have used recently-developed lithium drifted germanium gamma-ray detectors[1], to study the spectrum from the decay of the 155-day isomer of $Lu^{177}$. This isomer has been shown to be a three quasi-particle state of an odd proton and an uncoupled neutron pair which gives rise to the very high spin of 23/2[2,3].

Quite thorough studies have been made of the decay scheme of 155-day $Lu^{177}$ [2,3]. The isomer was shown to decay partly by isomeric transition to high-lying levels of the $K = 7/2^+$ [404] rotational band of $Lu^{177}$ and partly by $\beta^-$ decay to corresponding three quasi-particle states in $Hf^{177}$. Alexander, et al.[2] were able to confirm all the levels of the $Lu^{177}$ rotational band up to spin 17/2 and all the members of the two $Hf^{177}$ rotational bands up to spin 21/2 except for the spin 19/2 level of the $K = 7/2^-$ [514] band. The decay scheme is shown in Fig. 1.

We feel that this decay is a particularly important one for nuclear structure theory, involving as it does up to eight members of a rotational band in $Hf^{177}$, and it seemed worthwhile to confirm the proposed level schemes independently by definitive coincidence measurements and high-sensitivity gamma-ray spectroscopy using the newly-developed gamma-ray counters. In particular we were interested in filling the gap in the $7/2^-$ [514] band, in which there was no experimental evidence for the 19/2 state.

A sample of 155-day $Lu^{177}$ was prepared by irradiating natural lutetium metal for one 41-day cycle with a neutron flux of $5 \times 10^{14}$ in the ETR reactor at Arco, Idaho. After a waiting period of several months to permit the 7-day isomer to decay, the sample was dissolved and separated from long-lived activities of all other elements by means of an ion-exchange procedure.

The Ge(Li) counters which were used to obtain the spectra measured 1 cm. × 2 cm. in sensitive area and 6 mm. in depth. They were produced at this laboratory, as were the associated preamplifiers, amplifiers, and coincidence circuitry. The gamma-ray absorption efficiency of the counters was such that sources of less than one millicurie gave reasonable counting rates, enabling us to obtain the spectrum shown in Fig. 2 in about two days.

In Fig. 2 we show a gamma-ray spectrum of 155-day $Lu^{177}$ obtained with the Ge(Li) counter. Comparison with the bent-crystal data[2] shows that, although not as good for low energies, the resolution of the Ge(Li) counter excels that of the bent-crystal spectrometer for energies above about 300 keV. In two other respects the Ge(Li) counters are far superior to a bent-crystal spectrometer for these reasonably high energies. First, the efficiency is far higher; our experiments were done with sources of less than one millicurie. Secondly, the signal-to-noise ratio is very high for Ge(Li) counters, since there is little background due to incoherent scattering.

In Fig. 3 we show a spectrum of the region around 420 keV on an expanded scale. One observes a peak at about 426 keV which was not seen by Alexander, et al. This peak fits energetically as the cross-over transition between the missing 19/2 level and the 15/2 level in the $K = 7/2^-$ band of $Hf^{177}$. To establish that this 426 keV gamma ray actually was the 19/2 to 15/2 transition, we used two Ge(Li) counters and obtained a spectrum which was in coincidence with this gamma ray. Due to the low efficiency of the Ge(Li) counters, the coincidence counting rate was very low; hence only the more prominent

gamma rays could be seen. Peaks were observed in the coincidence spectrum at 113, 136, 249 and 341 keV and the other prominent peaks of the singles spectrum were either sharply reduced in intensity or else were completely missing, as shown in Fig. 4. Thus the 426 keV gamma ray must certainly come from the 19/2 to 15/2 transition in the $K = 7/2^-$ band of $Hf^{177}$. A careful search was made for the transitions which must feed the 19/2 level, namely the 21/2 to 19/2 cascade of about 243 keV or the 21/2 to 19/2 interband transition of about 284 keV. Neither peak could be found; the former because of the high Compton background in the low energy region, and the latter because resolution from the intense 281 keV peak was impossible. Even without this final proof, however, the position of the 19/2 level appears to be well established.

As an additional independent check of the decay scheme of Alexander, et al. we measured the spectra in coincidence with the 105, 413, and 418 keV transitions. Prominent peaks were again present or absent in agreement with the above decay scheme.

We conclude that the proposed decay scheme is confirmed in detail by the gamma-ray spectra and the coincidence work with Ge(Li) counters, and in particular that the 426 keV gamma ray is present, thus establishing the 19/2 member of the $7/2^-$ [514] band. These measurements indicate the power of the Ge(Li) counters for gamma ray spectroscopy. Accurate intensity determinations and nuclear orientation measurements with 155-day $Lu^{177}$ are underway.

## REFERENCES

*This work was done under the auspices of the U. S. Atomic Energy Commission.

1) A. J. Tavendale, in Proc. Int. Symp. Nuclear Electronics, Paris (1963) 235

2) P. Alexander, F. Boehm and E. Kankeleit, Phys. Rev. 133, (1964) B284

3) L. Kristensen, M. Jorgensen, O. B. Nielsen and G. Sidenius, Phys. Letters 8 (1964) 57

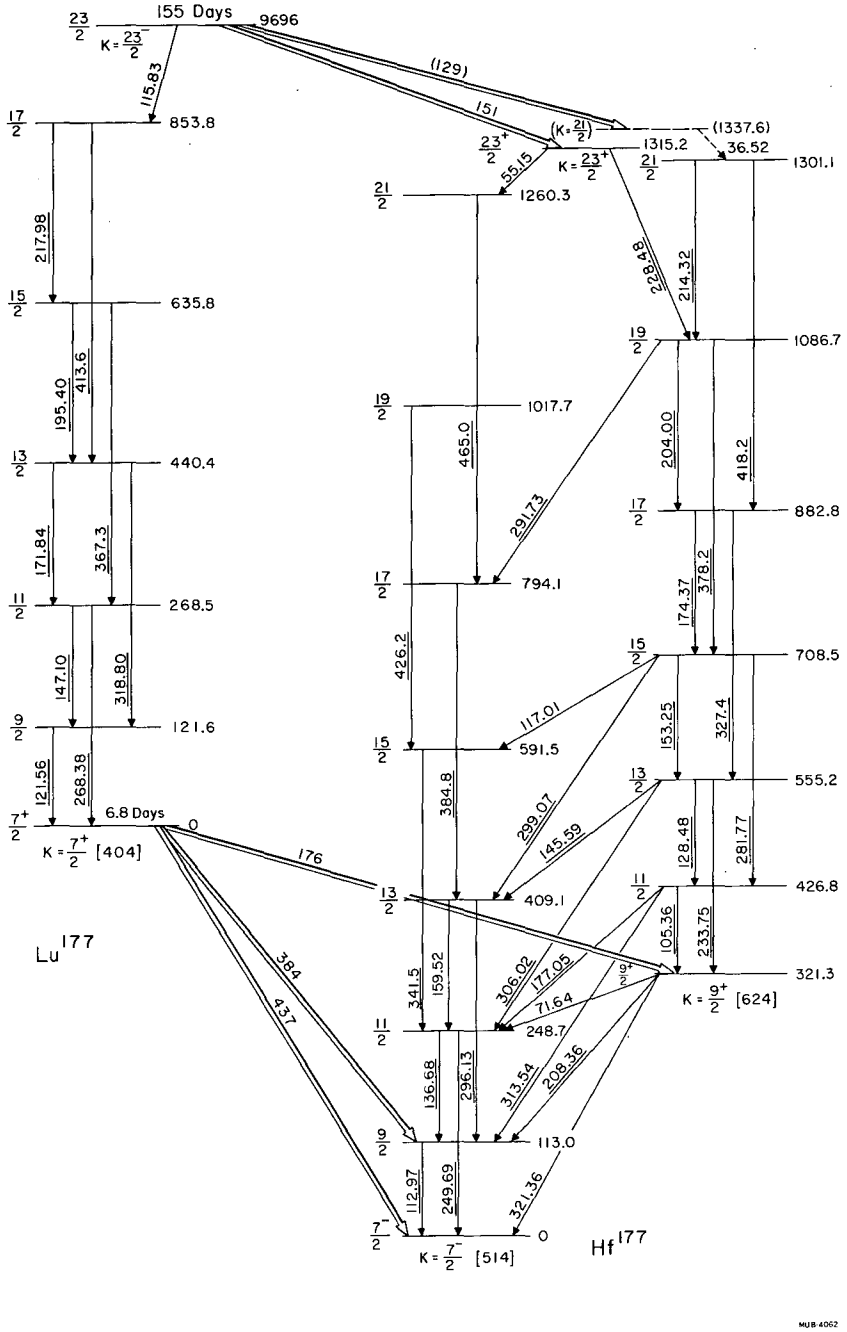
## FIGURE CAPTIONS

Fig. 1. Decay scheme of $Lu^{177}$ taken from Ref. 2. We have added the I = 19/2 level of the $K = 7/2^-$ [514] band and its associated gamma ray. Energies of gamma rays above 318 keV are ours. Gamma rays observed in this work are underlined.

Fig. 2. Gamma ray spectrum of 155-day $Lu^{177}$ with Ge(Li) detectors. The peaks are identified by their energy in keV.

Fig. 3. Detail of 155-day $Lu^{177}$ gamma ray spectrum showing the 426 keV transition. The experimental points are indicated as filled circles.

Fig. 4. Gamma ray spectrum of 155-day $Lu^{177}$ in coincidence with the 426 keV transition. Some of the peaks in coincidence with the 418 keV peak are also present (weakly), since a small amount of the 418 keV peak was accepted through the gate. Coincidence of the 113 with the 426 keV peak was determined in a separate run.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(129)
151
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(1337.6)
36.52
1315.2
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55.15
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1086.7
217.98
853.8
635.8
195.40
413.6
1017.7
465.0
204.00
418.2
882.8
440.4
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171.84
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794.1
174.37
378.2
268.5
426.2
708.5
147.10
318.80
117.01
153.25
327.4
121.6
591.5
555.2
121.56
268.38
384.8
299.07
145.59
128.48
281.77
6.8 Days
176
409.1
426.8
105.36
233.75
321.3
384
437
341.5
159.52
306.02
177.05
71.64
248.7
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113.0
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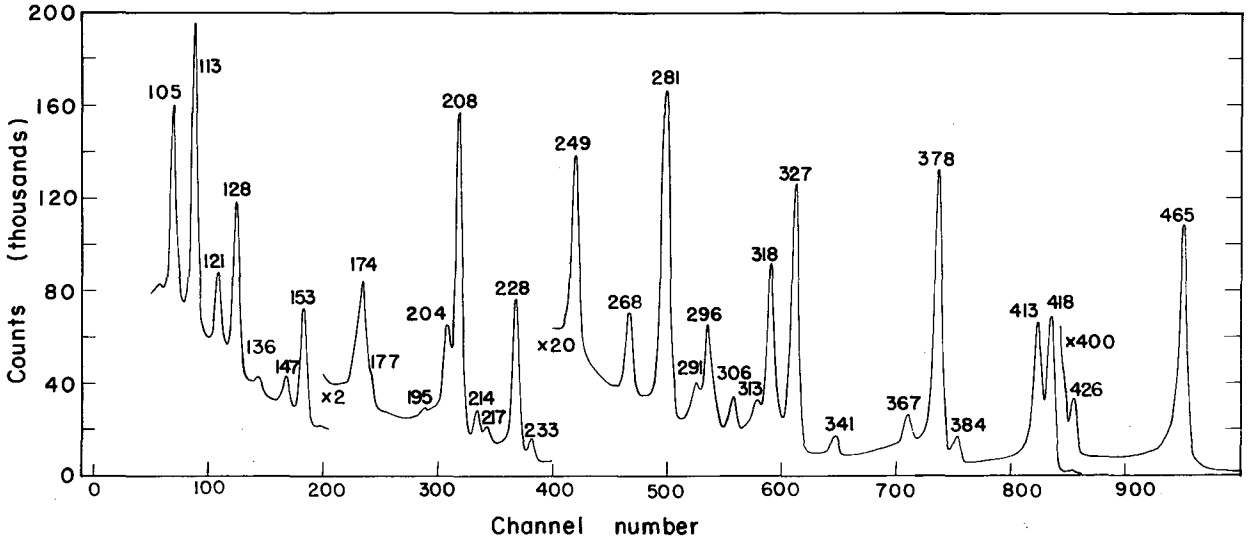
Lu177
Hf177
MUB 4062


Counts (thousands)
Channel number
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128
136
147
153
174
177
195
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208
214
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233
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268
281
291
296
306
313
318
327
341
367
378
384
413
418
426
465
x2
x20
x400
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400
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800
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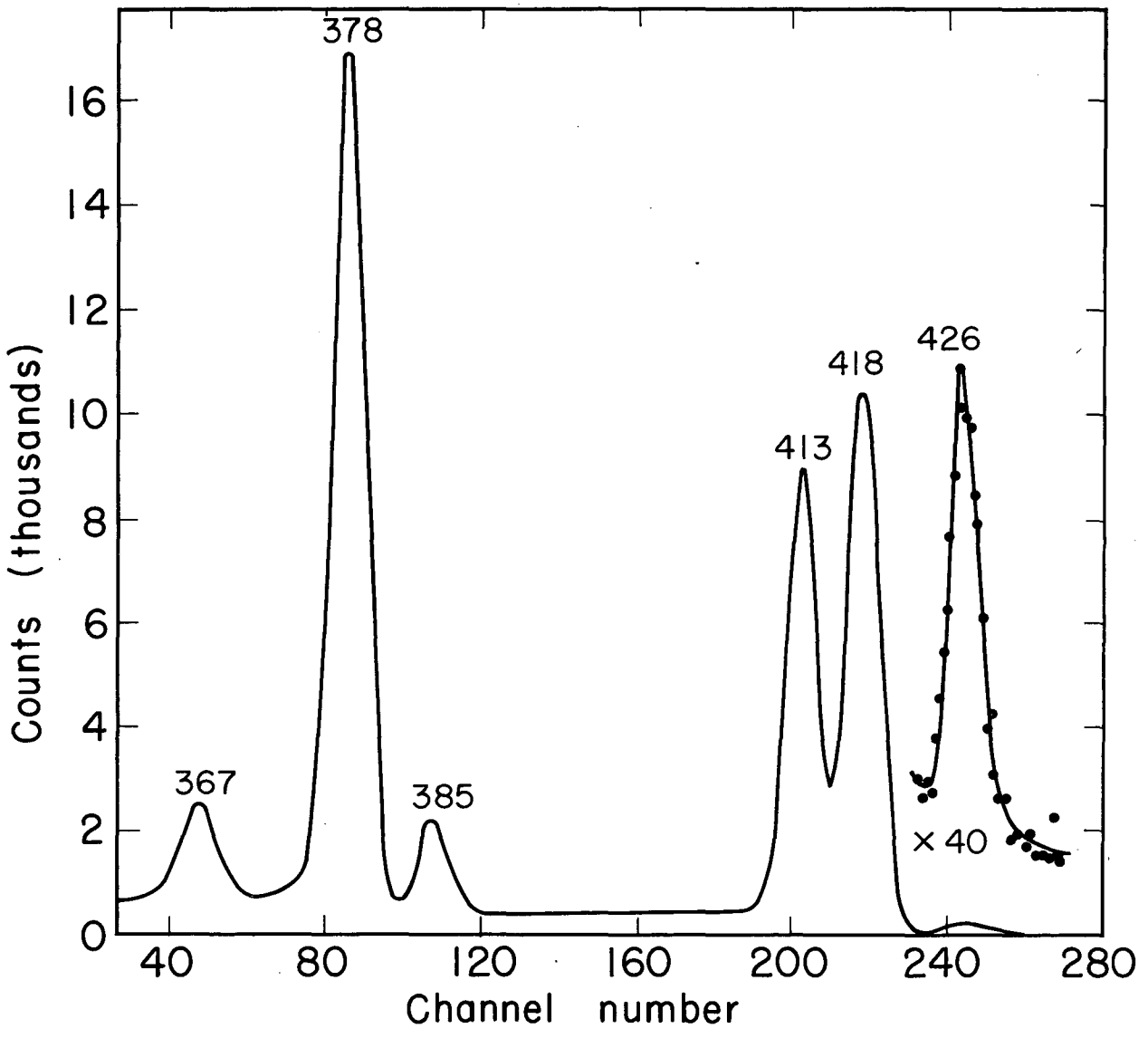
MUB-4061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385
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418
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× 40
Counts (thousands)
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4
6
8
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12
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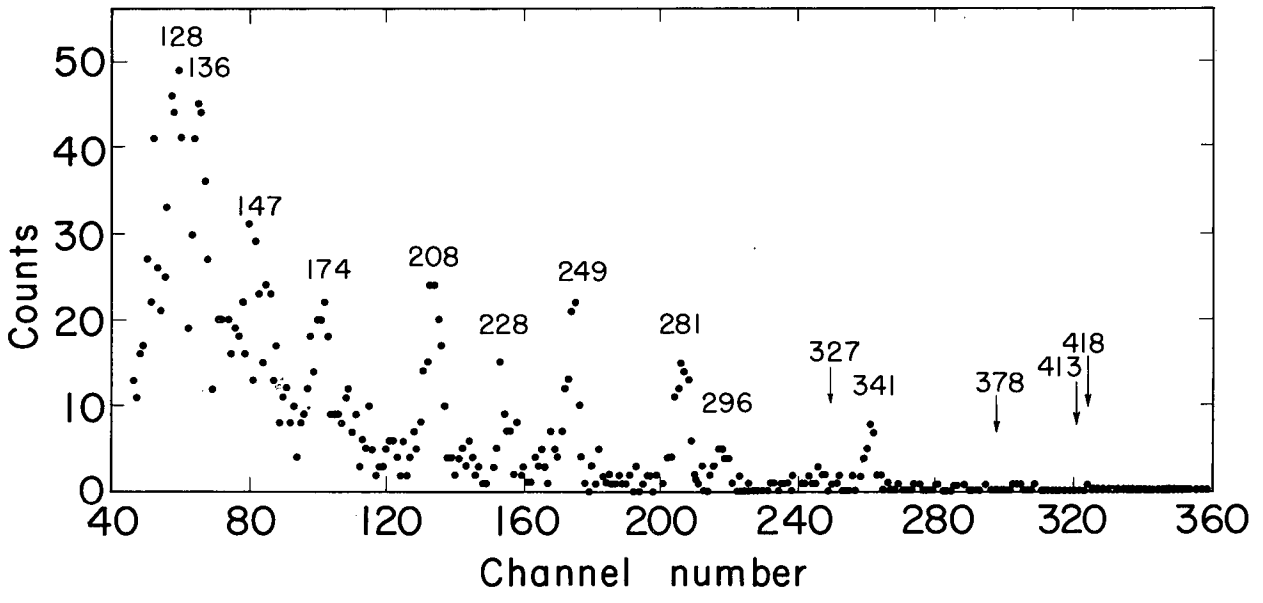
16
40
80
120
160
200
240
280
Channel number

MUB-4333


128
136
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208
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249
281
296
327
341
378
413
418
Counts
Channel number
0
10
20
30
40
50
40
80
120
160
200
240
280
320
360

MUB-4334

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